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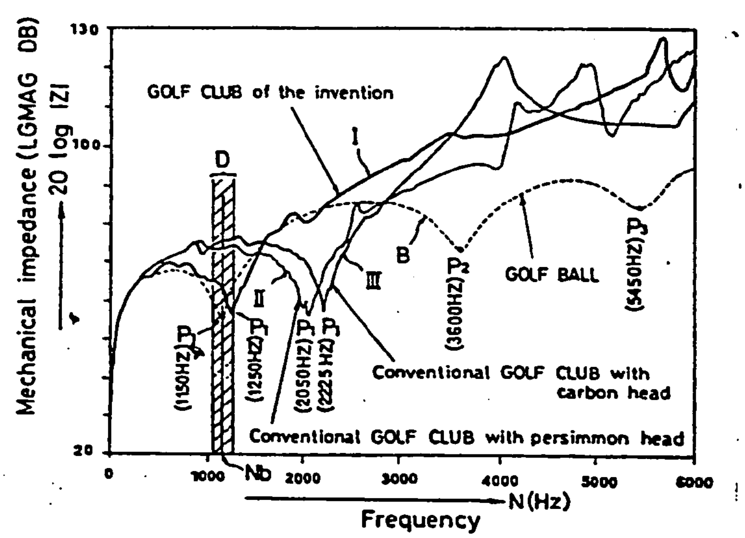
(54) A ball striking instrument.

(57) A ball striking instrument of such a structure that at least the main part of the instrument is fabricated so that the mechanical impedance (Z) of the ball striking part takes a minimum value (P1) in a range (D) of mechanical vibration frequency close to the frequency (Nb) at which the mechanical impedance (Z) of the ball to be struck takes a minimum value (P1).

FIG. 1



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A BALL STRIKING INSTRUMENT

The present invention relates to a ball striking instrument used for ball playing sports.

The invention will be described with respect to golf game as an example of ball playing sports. In the golf game, clubs are used as ball striking instruments. Action of the golf club for striking the golf ball can be summarized as follows:

Influence on the trajectory of a ball	.....	Influence on the degree of spin, trajectory angle, and running direction of a ball
Influence on the initial speed of a ball	.....	Influence on the club head speed Influence on the coefficient of restitution

Among the abovesaid influences, that on the degree of spin of a ball, trajectory angle, or ball running direction is explained from the viewpoint of dynamics with emphasis placed on the moment of inertia around the center of gravity of the club head. The speed of club head is explained in relation to swing of the club with emphasis placed on the club shaft.

Differently from the above, the coefficient of restitution is a problem of relation between the golf ball and the golf club, however, nothing has hitherto been described above influence on the coefficient of restitution exerted when the club (club head) collides with (strikes) the golf ball.

As component materials of conventional golf clubs, generally used are persimmon wood, ABS plastics, carbon-

fiber-reinforced plastics (abbreviated to CFRT in some cases hereinafter), aluminum, and stainless steel. A conventional view on the component materials is such that the harder, the material, the greater, the rebound of golf ball (the larger, the coefficient of restitution) and the initial speed thereof. Therefore, for example, carbon-fiber-reinforced plastics (CFRP) of higher fiber content, which have been regarded as "being hard and so having a large coefficient of restitution" are demanded.

The present invention has broken down a conventional common view as described above and, after experiments repeated many times, revealed a fact that there is an appropriate degree of hardness of ball striking instruments for providing the largest rebound and highest initial speed for the struck ball but an excess of hardness beyond this appropriate degree reduces the rebound of the ball. Further, the invention has disclosed that mechanical impedances of a ball and a ball striking instrument exert influences upon the rebound of the ball.

An object of the present invention is to provide a ball striking instrument which produces an increased coefficient of restitution at the time of striking a ball and adapts the initial speed of the ball to be close to the maximum — a ball striking instrument capable of sending a ball over a long distance.

Another object of the present invention is to make it possible to easily design a ball striking instrument having a large coefficient of restitution.

Other objects, features, and advantages of the present invention will become apparent from the detailed description given hereinafter in connection with the accompanying drawings.

According to the present invention, a mechanical impedance of ball striking part of the instrument takes the minimum value in a region of frequency mearby which a mechanical impedance of the ball takes the minimum value.

Action and effects of the present invention will be described as follows:

A ball shows a specific mechanical impedance correspondingly to the frequency of mechanical vibration imparted thereto as well as a striking part of an instrument shows a specific mechanical impedance. The frequency at which each mechanical impedance takes the minimum value corresponds to a natural frequency of vibration. The frequency at which a minimum value of mechanical impedance appearing at first while a frequency of the abovesaid mechanical vibration is gradually increased from zero corresponds to the primary natural frequency.

A coefficient of restitution is increased by constructing a ball striking instrument in such a way that the frequency at which the mechanical impedance of a striking part of the instrument takes the minimum value — the natural frequency of the striking instrument— is approximate to the frequency at which the mechanical impedance of the ball takes the minimum value — the natural frequency of the ball.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a characteristic-curve diagram showing variations in mechanical impedance corresponding to the frequency of vibration imparted by the vibrator on the basis of results of measurement performed on a golf club according to the present invention, two kinds of conventional golf clubs, and a struck ball;

Fig. 2 is a schamatic characteristic-curve diagram for describing the present invention and showing variations in mechanical impedance corresponding to the frequency of vibration imparted by the vibrator;

Fig. 3A through 3G are schematic views each showing a method of vibrating a ball or the whole or the striking

part of any of various ball striking instruments by means of the vibrator;

Fig. 4 is a block diagram showing an example of apparatus for measuring the mechanical impedance while imparting vibration by means of the vibrator;

Fig. 5A through 5D are front views of various kinds of ball striking instruments;

Fig. 6 is a view of a golf club as a ball striking instrument shown for the purpose of describing the mass distribution at the head thereof;

Fig. 7 is a perspective view for describing the structure of a golf club head;

Fig. 8 is a characteristic-curve diagram showing variations in mechanical impedance corresponding to the vibrations frequency obtained by the impact method in which golf clubs of the present invention, conventional ones, and the ball was actually struck;

Fig. 9A through 9C are schematic views for showing the impact method for measurement of mechanical impedance of a ball or the whole or the striking part of the instrument; and

Fig. 10 is a block diagram showing an example of apparatus for measuring the mechanical impedance by the impact method.

The present invention will be described by way of embodiments shown in the drawings as follows:

First, the term "mechanical impedance" in this invention is defined as the ratio between the magnitude of force acting upon a point and the speed of response of the other point when this force acts. That is to say, when an external force F acts and a response speed V is caused, the mechanical impedance Z is defined as:

$$Z = \frac{F}{V}$$

The term "ball striking instrument 1 according to the present invention" applies to a golf club 8, tennis racket 9, baseball bat 10, and table-tennis racket 11 to be used for ball playing sports, as shown in Figs. 5A through 5D.

In Fig. 2, shown is a diagram in which frequency N (unit: Hz) of mechanical vibration imparted to striking instruments 1 or a ball is indicated on the abcissa and a value obtained by multiplying the logarithm of absolute value or mechanical impedance Z by 20 is on the ordinate for observing a state of variation in mechanical impedance Z. As apparent from this drawing, mechanical impedances of the striking instruments 1a and 1b take primary minimum values at points P1, the secondary ones at points P2, and the tertiary and the fourth ones at points on the right side outlying from the drawing. As shown by the broken line in this drawing, the struck ball takes the primary and the secondary minimum values at points P1 and P2, respectively. (Further, the tertiary and successive minimum values lie outside the drawing.)

Frequencies at points P1, P2,...where these primary, secondary,... minimum values appear are so-called primary, secondary,... natural frequencies, which are settled according to [mass — spring] systems inherent to respective structures as striking instruments and balls.

Methods of measuring the abovesaid mechanical impedance Z are shown in Figs. 3A through 3E and Fig. 4. The reference numeral 12 indicates an electrically-or oil-hydraulically driven type vibrator, and a ball 2 is fixed to the sample setting table 13 of the vibrator. Also, a ball striking instrument such as golf club 8, tennis racket 9, baseball bat 10 or table tennis racket 11 is fixed to the setting table 13. That is, a ball striking part 3 among component members of the ball striking instrument 1 is fixed to the setting table 13 and subjected to vibration. A ball striking part 3 is a golf club head

8a in Fig. 3B, striking surface 9a for striking the tennis ball in Fig. 3C, a part for directly striking the baseball ball in Fig. 3D (a dotted part 10a in the drawing), or a blade part 11a of the table tennis racket 11.

A first acceleration pickup 14 is secured to the setting table 13 of the vibrator 12, and a second acceleration pickup 15 to the ball striking part 3 of the striking instrument 1 or the ball 2. Acceleration A1 of the setting table 13 of the vibrator 12 — external acceleration imparted to the ball striking instrument 1 or the ball — is outputted from the 1st acceleration pickup 14, and inputted into a dynamic signal analyzer 17 through a power unit 16. Acceleration A2 of the ball or the ball striking instrument is outputted from the 2nd acceleration pickup 15 and inputted into the dynamic signal analyzer 17 through the other power unit 18. A ratio between both values of acceleration — a transmission function $T = A2/A1$ — is found by the dynamic signal analyzer 17 and, by calculating this ratio in the region of frequency, a mechanical impedance $Z = F1/V2$ is obtained. This mechanical impednace Z indicated on a display 19 is as shown on the graph of Fig. 2. In measurement on embodiments of the present invention depending on measuring apparatus as shown in Figs. 3 and 4, used were those made by such makers and of such types as listed in the following Table 1.

Table 1 Apparatus used for measurement

Measuring apparatus		Type	Name of Maker
Dynamic signal analyzer 17		HP-5420A	Yokogawa-Hughlet-Packer (YHP) Co.,Ltd. (Japan)
Vibrator	Body proper 12	PET-01	K.K Kokusai Kikai-shindo kenkyusho (IMV CORPORATION) (Japan)
	Controller	PET-0A	
Acceleration pickup 14,15		303A03	PCB
Power unit 16,18		480D06	PCB

The measuring methods using the above-listed measuring apparatus provide an advantage enabling the user to clearly confirm the primary minimum value of mechanical impedance Z.

With reference to Fig. 2 and Figs. 3A through 3E, on the assumption that the mechanical impedance Z of the ball 2 takes a primary minimum value P1 at frequency Nb, mass distribution and other physical characteristics, such as a spring constant, of component parts of a ball striking instrumnt 1 according to the present invention are selectively determined so that the mechanical impedance Z of the instrument may take a primary minimum value in the region D of frequency expressed by the following formula ①— a hatched part in Fig. 2:

$$(1-n) \cdot Nb \leq N \leq (1+n) \cdot Nb \text{............} ①$$

where: $0 \leq n \leq 0.3$

Concretely describing, a ball striking instrument 1a shows a primary minimum value in the neighborhood of the lower end of the frequency N satisfying the above formula ① whereas the other instrument 1b shows a primary minimum value in the neighborhood of the upper end.

By substituting n = 0.3, n = 0.2, n = 0.1, and n = 0.05 for the formula ①, frequency regions D are respectively expressed as follows:

$$0.7Nb \leq N \leq 1.3Nb \quad \text{②}$$

$$0.8Nb \leq N \leq 1.2Nb \quad \text{③}$$

$$0.9Nb \leq N \leq 1.1Nb \quad \text{④}$$

$$0.95Nb \leq N \leq 1.05Nb \quad \text{⑤}$$

A ball striking instrumet 1 of the present invention is fabricated so that a primary minimum value P1 of the mechanical impedance Z may lie in the frequency region satisfying any one of the above formula ②, ③, ④, and ⑤. In other words, a ball striking instrument 1 is fabricated in such a way that the mechanical impedance Z thereof takes a primary minimum value P1 in a region D of frequency corresponding to 70% - 130%, 80% - 120%, 90% - 110%, or 95% - 105% of the frequency Nb at which the mechanical impedance Z of the ball 2 takes a primary minimum value P1. A sufficiently large coefficient of restitution can be obtained at a frequency corresponding to 70% - 130% of Nb, however, the strongest repulsion of ball can be obtained at 95% - 105%.

Fig. 1 shows results of measurement on golf clubs and a golf ball depending on the same measuring apparatus and the same method as employed in the case shown in Fig. 2, that is , the method of vibration using the vibrator.

In this drawing, a characteristic of the golf ball is shown by the broken line B. It can be understood that a primary minimum value P1 appears at a frequency Nb = 1,150 Hz, a secondary and tertiary ones at N = 3,600 Hz and N = 5,450 Hz, respectively. As regards golf balls sold on the market, a frequency Nb at which the primary

minimum value P1 appears varies according to the structure (one-component ball, two-component ball, and yarn-wound ball) of the ball, however, lies in the range as shown by a formula

$$600\ Hz \leq Nb \leq 1{,}600\ Hz \quad \cdots\cdots\cdots\ ⑥$$

at a temperature of 25℃ for measurement.

Results of measurement of mechanical impedances of conventional golf clubs are shown by fine continuous line II and III in Fig. 1. The golf club having the mechanical impedance as indicated by the continuous line II is a conventional wood golf club with a head made of persimmon wood, in which the frequency N corresponding to the primary minimum value P1 is 2,050 Hz. Another club having the mechanical impedance as indicated by the continuous line III is a conventional wood golf club with a head made of CFRP, in which the frequency corresponding to the primary minimum value P1 is 2,225Hz. Accordingly, the frequency at which the mechanical impedance Z of the conventional type golf club takes a primary minimum value P1 is far distant from the region D of frequency in the vicinity of frequency at which the mechanical impedance Z of the golf ball takes a primary minimum value P1.

A wood type golf club, in which mass distribution in the head and shaft, spring constant, and damping coefficient are determined on the basis of the abovesaid technical concept, draws a curve representing a mechanical impedance as shown by the thick continuous line I and the frequency corresponding to the primary minimum value P1 of mechanical impedance Z was 1,250 Hz. That is, the above value corresponds to a result obtained from inserting n = 0.087 in the formula ①. A minimum value P1 of the mechanical impedance of this golf club lies in the frequency region D in Fig. 1 drawn so as to satisfy the formula ④

Results of comparing the performance of a golf club (referred to as I) of the present invention with those of a conventional club with persimmon head (II) and another conventional club with carbon head (III) shown in Fig. 1 are listed in Table 2. A two-component golf ball (covered with ionomer synthetic resin) was used for test shot.

Table 2 Comparison of performances between a golf club of the present invention and conventional clubs

	Component material		Head speed immediately before shot Vh m/sec	Ball speed immediately after shot (initial speed) Vb m/sec	Coefficient of restitution Vb/Vh	Carry (m)
	Material of head	Insert of impact face				
Embodiment of the invention I	Persimmon	Ionomer plastics	45.15	62.53	1.3850	192.4
Conventional club II	Persimmon	ABS plastics	45.16	61.31	1.3576	188.6
Conventional club III	Carbon	CFRP laminated board	45.08	61.08	1.3549	186.9

From Table 2 and Fig. 1, the following facts become apparent. As the frequency Nb at which the mechanical impedance Z of a golf ball takes a primary minimum value P1 — the primary natural frequency — and the frequency at which the mechanical impedance Z of a golf club takes a primary minimum value P1 — the primary natural frequency — approach closer to each other, a coefficient of restitution increases and, accordingly, a carry of ball increases. The golf club I of the present invention, when compared with conventional clubs II and III in terms of carry of ball, showed a carry about 4 to 6 m longer than those by conventional clubs II and III. Whether an increase of 1 m in the carry of ball is possible or not is a big concern of players and, therefore, the abovesaid increase (about 4 to 6m) in the carry obtained from a golf club of the present in -vention is quite significant. Thus, from Table 2, a remarkable increase in the carry of ball can be confirmed.

In comparison with the conventional golf club in which a primary minimum value P1 of the mechanical impedance Z is observed at a frequency of 2,000 Hz or more, a club according to the present invention is fabricated so that a primary minimum value P1 may appear in a region of frequency comparatively low as ranging from 600 to 1,600 Hz in condition of the primary minimum value of mechanical impedance Z of various kinds of golf balls.

Further concrete description of a golf club is such that, with reference to Fig. 6, when assuming a cutting line a - b which passes through the center 5 of the ball striking face 4 and extends perpendicularly with respect to the face 4 and dividing the club head 8a into three parts with two planes La and Lb which pass through two points Qa and Qb dividing the line a - b into three equal segments and extend perpendicularly to the line a - b, the center of gravity G of the club head 8a lies in a position near the plane La. That is, a golf club is fabricated so that the center of gravity G of the head

thereof may lie distant from the striking face 4 by a length equal to one-thirds of the total length of the segment over the head and a ratio of mass between three divided parts may be as follows:

$$M1 : M2 : M3 = 5 : 3 : 2$$

(The above ratio is almost the same as that in the conventional club head.)

As shown in Fig. 7, a material having a spring constant k markedly lower than those ever employed as an insert 7 for the striking face 4. In the embodiment I of the present invention shown in Table 2 and Fig. 1, an insert 7 having a thickness t ≒ 8㎜, width W ≒ 40 ㎜, height H ≒ 40 ㎜, and spring constant k ≒ 11,000 ㎏/㎝ when compression is exerted on an area of 20㎜ diameter has been used.

In this way, a golf club having a primary minimum value P1 of mechanical impedance which appears at a specified frequency within the range from 600 to 1,600 Hz — a golf club having the primary natural frequency (resonance frequency) — can be obtained by the use of a material of insert 7 having a spring constant k significantly lower than those of conventional ABS plastics, laminated board of carbon-fiber-reinforced plastics (CFRP), or metallic plate such as aluminum. Particularly, a structure as above is advantageous for maintaining mass distribution in and the configuration of the conventional golf club as they are.

Since the mechanical impedance of a body is governed by mass distribution, spring constant, and damping coefficient of the body, it is also possible to compose the whole of a golf club by varying the distribution of spring constants of masses M2 and M3 shown in Fig. 6, distribution of masses themselves, or kind of material and structure so that the primary minumum value may appear in a region of frequency ranging from 600 to 1,600 Hz. It is preferable to

adjust the spring constant by the use of engineering plastics such as polycarbonate as a material of insert for adapting the golf club to show a primary minumum value P1 in the same way as above.

In the abovesaid embodiment, as shown in Fig. 3B, a mechanical impedance Z of the ball striking part 3 is measured while the entire body of a golf club 8 for making up a structure in which the mechanical impedance Z takes a primary minimum value in a specified frequency region D, however, there is another preferred way to vibrate only the ball striking part 3 — a club head 8a — for measuring a mechanical impedance Z and to make up a structure in which the mechanical impedance takes a primary minimum value P1 is a specified frequency region D.

In the case of ball striking instruments such as tennis racket 9, baseball bat 10, and table tennis racket 11 shown in Figs. 5B through 5D, respectively, by finding a frequency Nb at which the mechanical impedance of each of balls for tennis, baseball, and table tennis shows a primary minimum value P1 and by appropriately determining mass distribution and spring constant of each of the rackets 9 and 11 and the bat 10 according to material, configuration, and structure thereof so that a primary minimum value P1 of the striking instrument may appear in a region D of frequency close to the previously found frequency Nb, the initial speed of a ball immedeately after struck and a coefficient of restitution of the ball are increased.

In fact, as a result of tests performed many times by the inventors of the present invention in accordance with the method shown in Fig. 3A and Fig. 4 — a method of vibration by means of the vibrator 12 — in which values of mechanical impedances Z of many kinds of balls for tennis, baseball, and table tennis were measured, it has been found that a frequency Nb at which the mechanical impedance Z of each ball shows a primary minimum value P1 — a primary

natural frequency — lies within the range from 110 to 500 Hz.

It is preferable to determine mass distribution and spring constant of the tennis racket so that the mechanical impedance Z thereof takes a primary minimum value P1 in a region of frequency ranging from 110 to 500 Hz after vibrating the entire body of racket 9 by means of the vibrator 12 as shown in Fig. 3c (or only the ball striking face, not shown in the drawing) for measurement as shown in Fig. 4.

For the baseball bat 10, it is preferable to set mass distribution and spring constant in a way that the mechanical impedance Z takes a primary minimum value P1 in a region of frequency ranging from 110 to 500 Hz when the bat 10 is vibrated by the vibrator 12 and the mechanical impedance is measured as shown in Fig. 4.

Also, it is advantageous for the table tennis racket 11 to set mass distribution and spring constant so that the mechanical impedance Z takes a primary minimum value P1 in a region of frequency ranging from 110 to 500 Hz when the entire body of the racket 11 is vibrated as shown in Fig. 3E or only the blade part is vibrated as shown in Fig. 3G and subjected to measurement as shown in Fig. 4.

Another method of measuring the mechanical impedance Z is shown in Figs. 9A, 9B, 9C, and Fig. 10. The reference numeral 20 represents an impact hammer which strikes a ball 2 or a ball striking instrument suspended by a thin thread 21 or the like. A force pickup 22 for sensing impact force is provided for the impact part 20a of the impact hammer 20. In Figs. 9B and 9C, a golf club 8 as a ball striking instrument 1 is shown, and the whole of the golf club or only the head 8a as the main part (striking part) of the club is suspended as shown in Fig. 9B or 9C, respectively, the face of the club head 8a being impacted directly with the impact hammer 20.

An acceleration pickup 15 is fixed to a ball 2 and a striking part 3. As shown in Figs. 9A through 9C, when the

ball 2 or the striking part 3 is struck with the impact hammer 20 as indicated by the arrow mark G, the force F1 applied by the hammer 20 — the external force acting on the ball 2 or the striking part 3 — is outputted while turned into electric signal to be inputted into the dynamic signal analyzer 17 through the power unit 16. From the 2nd acceleration pickup 15, acceleration A2 transformed into electric signal is outputted (in the same way as the vibration method by the use of the vibrator as described with reference to Fig. 4) and also inputted into the abovesaid dynamic signal analyzer 17 through another power unit 18. A ratio between the abovesaid acceleration A2 and the external for F1 — a transfer function T = A2/F1 — is obtained from this dynamic analyzer 17 and calculated in the frequency region for finding the mechanical impedance Z = F1/V2. When such mechanical impedance is indicated on the display 19, a graph as shown in Fig. 8 is obtained. The impact hammer 20 used for testing is made by PCB Corporation and of Type 208A03, the dynamic signal analyzer 17, power units 16 and 18, and pickups 15 and 22 being made by the same maker and of the same type as those referred to in Table 1 describing the vibration method.

Fig. 8 shows results of measuring the mechanical impedance Z of the golf club 8 and golf ball 2 obtained by the impact method.

As shown by the broken line Bi in Fig. 8, it can be understood that the golf ball has the mechanical impedance whose minimum values P1 appear at two to five points in a region of frequency ranging from 0 to 10,000 Hz. A primary minimum value Pi by the impact method — a value corresponding to the secondary minumum value by the vibration method — appears at a frequency N ranging from about 2,000 to 4,000 Hz.

Results of measurement of the mechanical impedance of the conventional wood type golf club by the impact method are shown by fine alternate along and two-dash lines Ⅱi and Ⅲi in Fig. 8. As apparent from the indication by these lines,

distinct minimum values are not observed in a region of frequency of 0 - 10,000 Hz.

For wood type golf clubs according to the present invention as ball striking instruments, mass distribution, spring constant, and attenuation constant of the club head and club shaft are determined so that a minimum values Pi may appear, as shown by continuous lines Ii and Ii' in a region of frequency ranging from 1,500 to 8,000 Hz, preferably from 2,000 to 6,000 Hz. Particularly, in view of a minimum value of golf ball appearing at a frequency from about 3,000 to 4,000 Hz when measured by the impact method, the best way is to fabricate a wood type golf club so that a minimum value Pi may appear in a region of frequency ranging from 2,000 to 4,500 Hz.

Table 3 shows results of comparison between materials of club heads, kinds of inserts, and functions of golf club Ii and Ii' of the present invention and conventional clubs IIi and IIIi. The ball used for testing was a two-component ball covered with ionomer plastics and having characteristics shown by the broken line in Fig. 8.

Table 3 Comparison of function of golf clubs embodying the invention with that of conventional clubs.

	Component material of golf club		Head speed immediately before shot Vh m/sec	Ball speed immediately after shot (initial speed) Vb m/sec	coefficient of restitution Vb/Vh
	Material of haead	Insert for impact face			
Embodiment of the Invention Ii	Carbon	Ionomer plastics, spring constant of 10,000kg/cm	45.18	62.50	1.3862
Embodiment of the invention Ii'	Carbon	Ionomer plastics, spring constant of 8,000kg/cm	45.24	63.86	1.4116
Conventional club IIi	Persimmon	ABS plastics, spring constant of 40,000kg/cm	45.20	61.81	1.3675
Conventional club IIIi	Carbon	CFRP ply board, spring constant of 80,000kg/cm	45.25	61.87	1.3673

Note) Thicknesses of inserts for Ii, Ii', IIi and IIIi are 8 mm in common, and a spring constant of insert is based on compression exerted on an area of 25 mm diameter.

The following can be understood from the above Table 3 and Fig. 8. Coefficients of restitution of golf clubs Ii and Ii' of the present invention showing a minimum value at frequencies of 5,250 Hz and 3,800 Hz, respectively, are far larger than those of club heads (conventional clubs II i and III-i) not showing minimum values at frequencies ranging from 0 to 1,000 Hz when measured by the impact method. Accordingly, golf clubs of the present invention ensure an increase in the carry of ball by 2 to 8 m longer than that by conventional clubs.

It is preferable to design a golf club, after performing measurement only at the ball striking part 3 — club head 8 — by the impact method, so that a minimum value P1 of the mechanical impedance Z may appear in the abovesaid region of specified frequency. Mechanical impedances Z of other ball striking instruments that the golf club can be obtained by the impact method. It is also preferable to determine mass distribution and spring constant of the whole or the main part of respective striking instruments so as to satisfy the abovesaid conditions.

It is a matter of course that the present invention applies to ball striking instruments for sporting other than the foregoing, for example, the stick for (ice) hockey, croquet, and mallet.

CLAIMS:

1. A ball striking instrument characterized in that at least a main part thereof is composed so that the mechanical impedance (Z) of a ball striking part (3) thereof has a minimum value (P) in a range (D) of frequency in the neighborhood of a frequency (Nb) at which the mechanical impedance (Z) of a ball (2) to be struck has a minimum value (P).

2. The ball striking instrument according to Claim 1, wherein values of mechanical impedance (Z) of said ball (2) and striking part (3) are measured by imparting vibration generated by a vibrator (12) to said ball (2) and striking part (3).

3. The ball striking instrument according to Claim 1, wherein the mechanical impedances (Z) of said ball (2) and striking part (3) are measured with application of vibration by the vibrator (12) and a primary minimum value (P1) of the mechanical impedance (Z) of said striking part (3) lies in the range (D) of frequency in the neighborhood of the frequency (Nb) at which the mechanical impedance (Z) of said ball (2) takes a primary minimum value (P1).

4. The ball striking instrument according to Claim 3, wherein said range (D) of frequency is set so that a frequency (N) therein may be equal to 70 to 130% of the frequency (Nb) at which the mechanical impedance (Z) of said ball(2) takes the primary minimum value (P1).

5. The ball striking instrument according to Claim 4, wherein said range (D) of frequency is set so that a frequency (N) therein may be equal to 80 to 120% of the frequency (Nb) at which the mechanical impedance (Z) of said ball (2) takes the primary minimum value(P1).

6. The ball striking instrument according to Claim 5, wherein said range (D) of frequency is set so that a frequency (N) therein may be equal to 90 to 110% of the frequency (Nb) at which the mechanical impedance (Z) of said ball (2) takes the primary minimum value (P1).

7. The ball striking instrument according to Claim 6, wherein said range (D) of frequency is set so that a frequency (N) therein may be equal to 95 to 105% of the frequency (Nb) at which the mechanical impedance (Z) of said ball (2) takes the primary minimum value (P1).

8. The ball striking instrument according to Claim 7, wherein the frequency (N) at which the mechanical impedance (Z) of said ball striking part (3) takes a primary minimum value (P1) is equal to the frequency (Nb) at which the mechanical impedance (Z) of said ball (2) takes the minimum value (P).

9. The ball striking instrument according to any one of claims 1 to 8, wherein the entire body of the instrument is in the shape of or is a golf club (8) and the mechanical impedance (Z) of its club head for striking the ball (2) takes the primary minimum value (P1) in the range (D) of frequency ranging from 600 to 1,600 Hz.

10. The ball striking instrument according to any one of claims 1 to 8, wherein the entire body of the instrument is in the shape of or is a tennis racket (9) and the mechanical impedance (Z) of its face for striking the ball (2) takes the primary minimum value (P1) in the range (D) of frequency ranging from 110 to 500 Hz.

11. The ball striking instrument according to any one of claims 1 to 8, wherein the entire body of the instrument is in the shape of or is a baseball bat (10) and the mechanical impedance (Z) of its part (10a) for striking the ball (2) takes the primary minimum value (P1) in the range (D) of frequency ranging from 110 to 500 Hz.

12. The ball striking instrument according to any one of claims 1 to 8, wherein the entire body of the instrument is in the shape of or is a table tennis racket (11) and the mechanical impedance (Z) of its face for striking the ball (2) takes the primary minimum value (P1) in the range (D) of frequency ranging from 110 to 500 Hz.

13. The ball striking instrument according to Claim 1, wherein the mechanical impedances (Z) are measured by an impact method in which said ball (2) and striking part (3) are actually struck by an impact hammer (20).

14. The ball striking instrument according to Claim 13, wherein the mechanical impedance (Z) of the ball striking part (3) has a minimum value (Pi) in the range (D) of frequency ranging from 1,500 to 8,000 Hz.

15. The ball striking instrument according to Claim 13, wherein the mechanical impedance (Z) of the ball striking part (3) has a minimum value (Pi) in the range (D) of frequency ranging from 2,000 to 6,000 Hz.

16. The ball striking instrument according to Claim 13, wherein the mechanical impedance (Z) of the ball striking part (3) has a minimum value (Pi) in the range (D)) of frequency ranging from 2,000 to 4,500 Hz.

17. A method of striking a ball (2) in which the ball (2) is struck with an instrument having a striking part (3) whose mechanical impedance (Z) has a minimum value (P) in a range (D) of frequency in the neighborhood of a frequency (Nb) at which the mechanical impedance (Z) of said ball (2) has a minimum value.

18. A method of manufacturing a ball striking instrument for striking a ball (2) of known mechanical impedance characteristic having a minimum value (P) at a known frequency (Nb), in which method at least a part (3) of the instrument is constructed so that the mechanical impedance thereof has a minimum value (P) in a range of frequency (D) in the neighborhood of said known frequency (Nb).

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FIG. 1

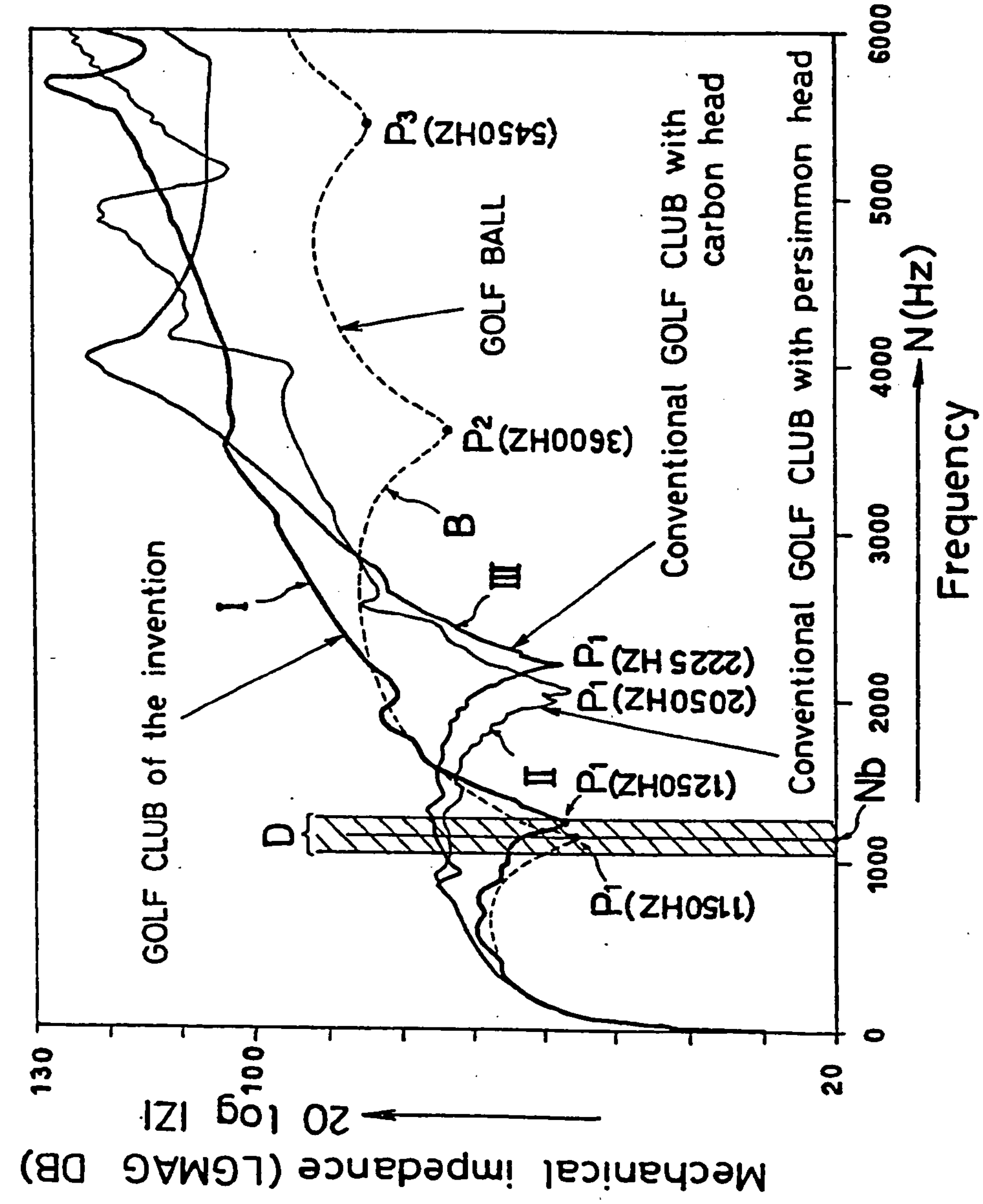
Mechanical impedance (LGMAG DB)
20 log |Z|
130
100
20
0
1000
2000
3000
4000
5000
6000
N(Hz)
Frequency
Nb
D
GOLF CLUB of the invention
I
II
III
B
GOLF BALL
Conventional GOLF CLUB with carbon head
Conventional GOLF CLUB with persimmon head
P1 (1150HZ)
P1 (1250HZ)
P1 (2050HZ)
P1 (2225 HZ)
P2 (3600HZ)
P3 (5450HZ)

FIG. 2

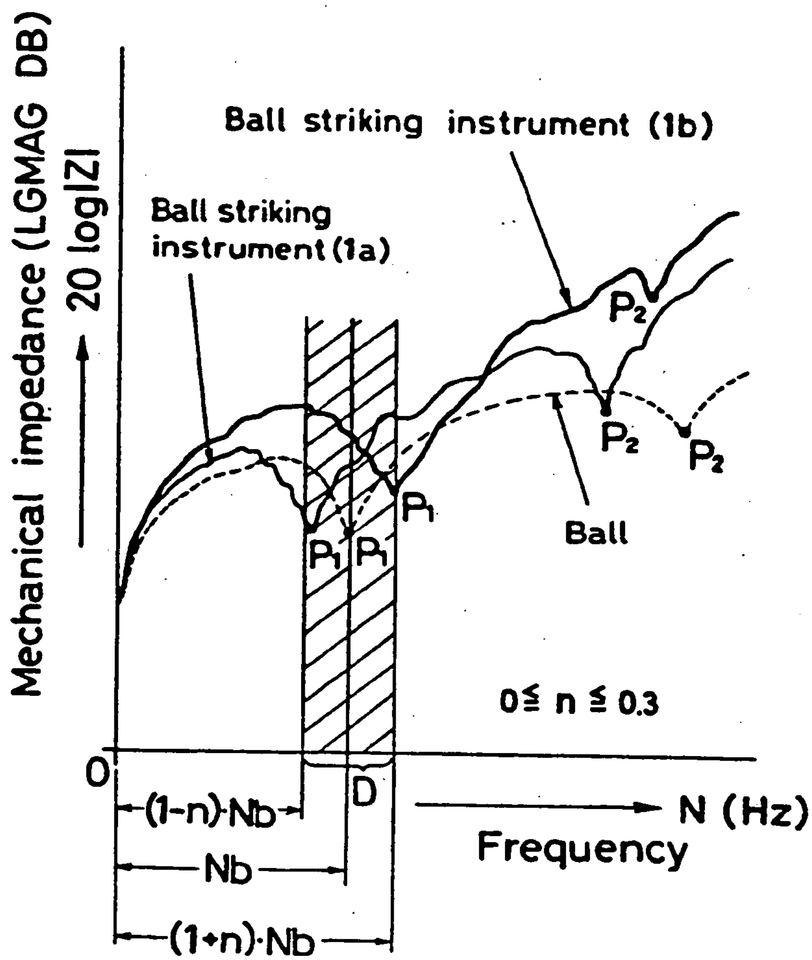
Mechanical impedance (LGMAG DB)
20 log|Z|
Ball striking instrument (1b)
Ball striking
instrument (1a)
P2
P2
P2
P1
P1
P1
Ball
0≦ n ≦ 0.3
0
D
(1-n)·Nb
Nb
(1+n)·Nb
N (Hz)
Frequency

FIG. 3A

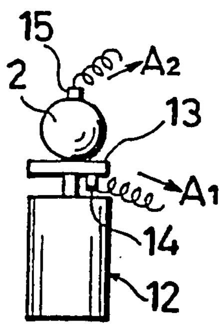

FIG. 3B

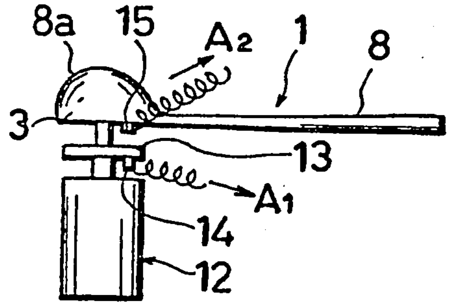

FIG. 3C

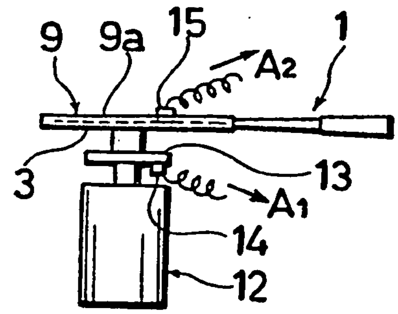

FIG. 3D

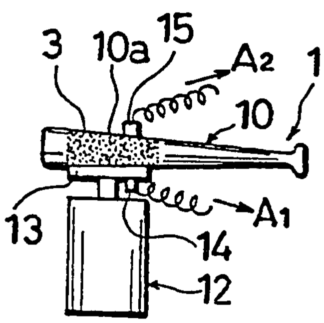

FIG. 3E

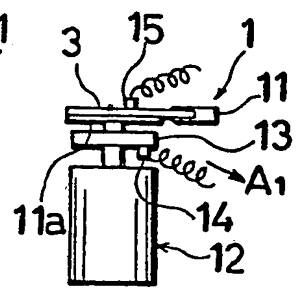

FIG. 3F

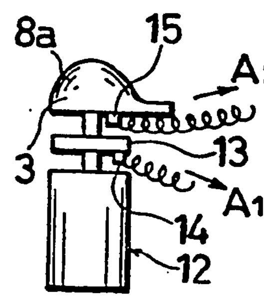

FIG. 3G

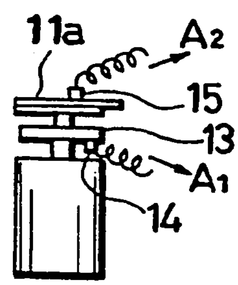

FIG. 4

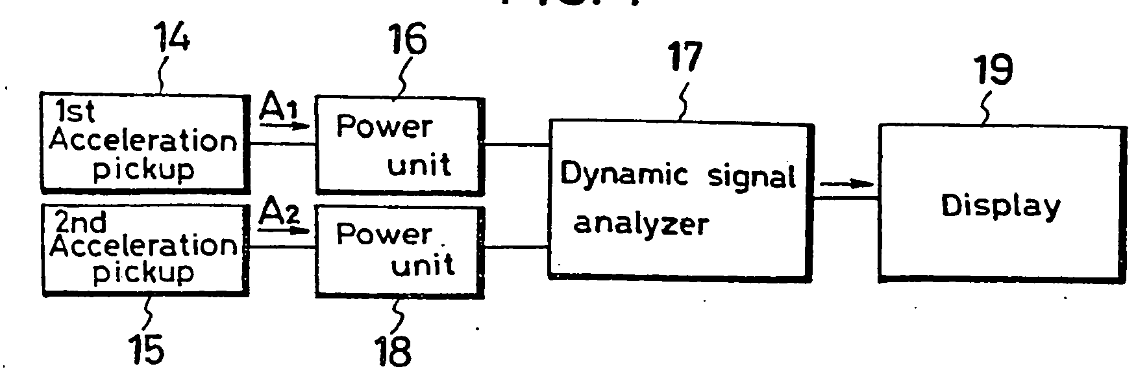

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FIG. 5A FIG. 5B FIG. 5C FIG. 5D

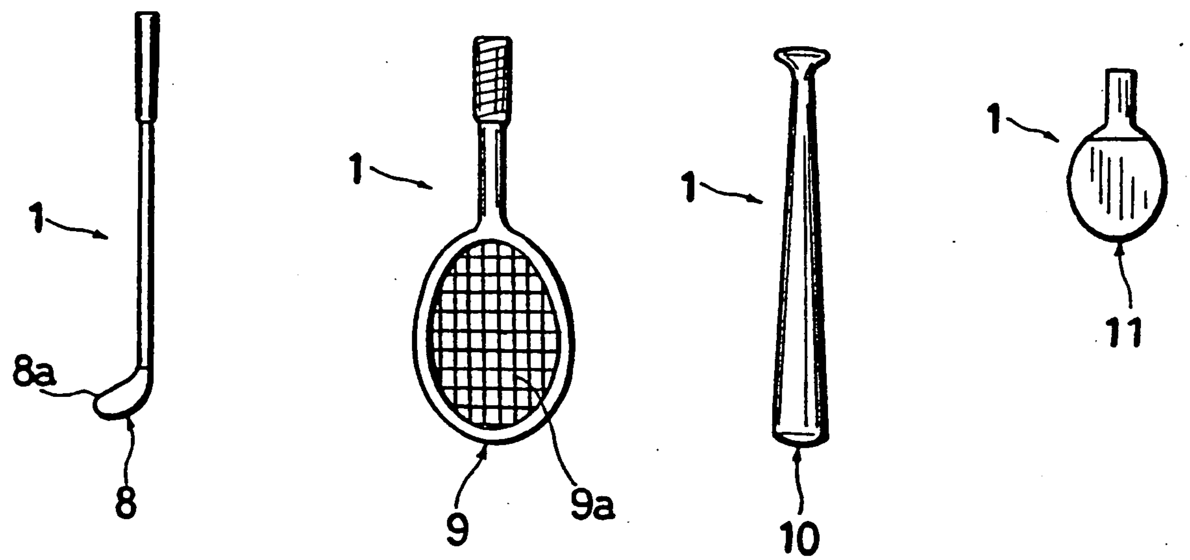


FIG. 6

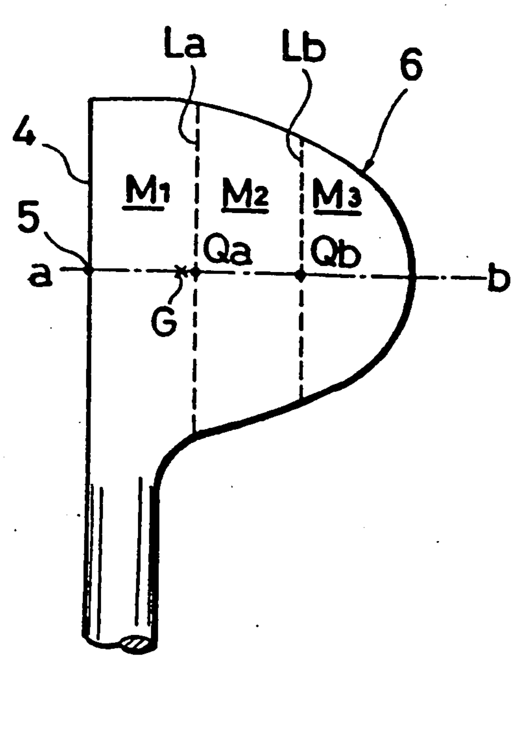


FIG. 7

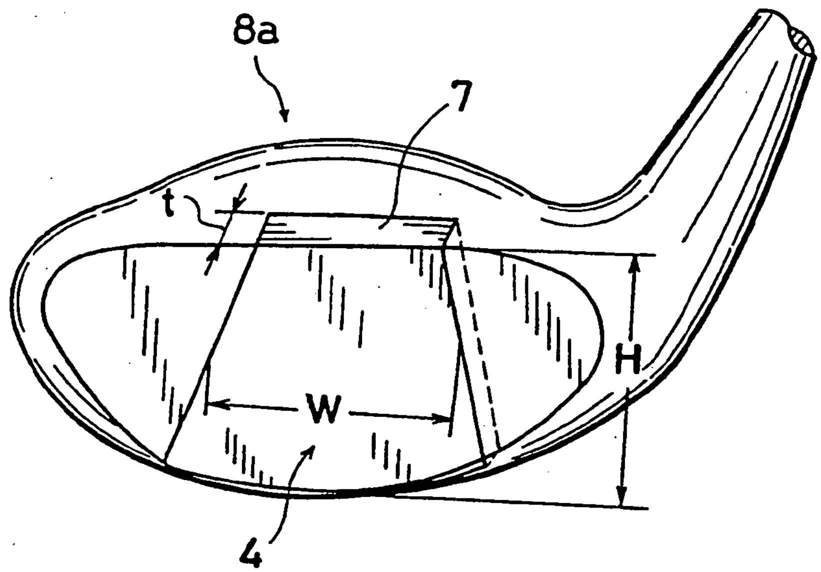

8a
7
t
H
W
4

FIG. 8

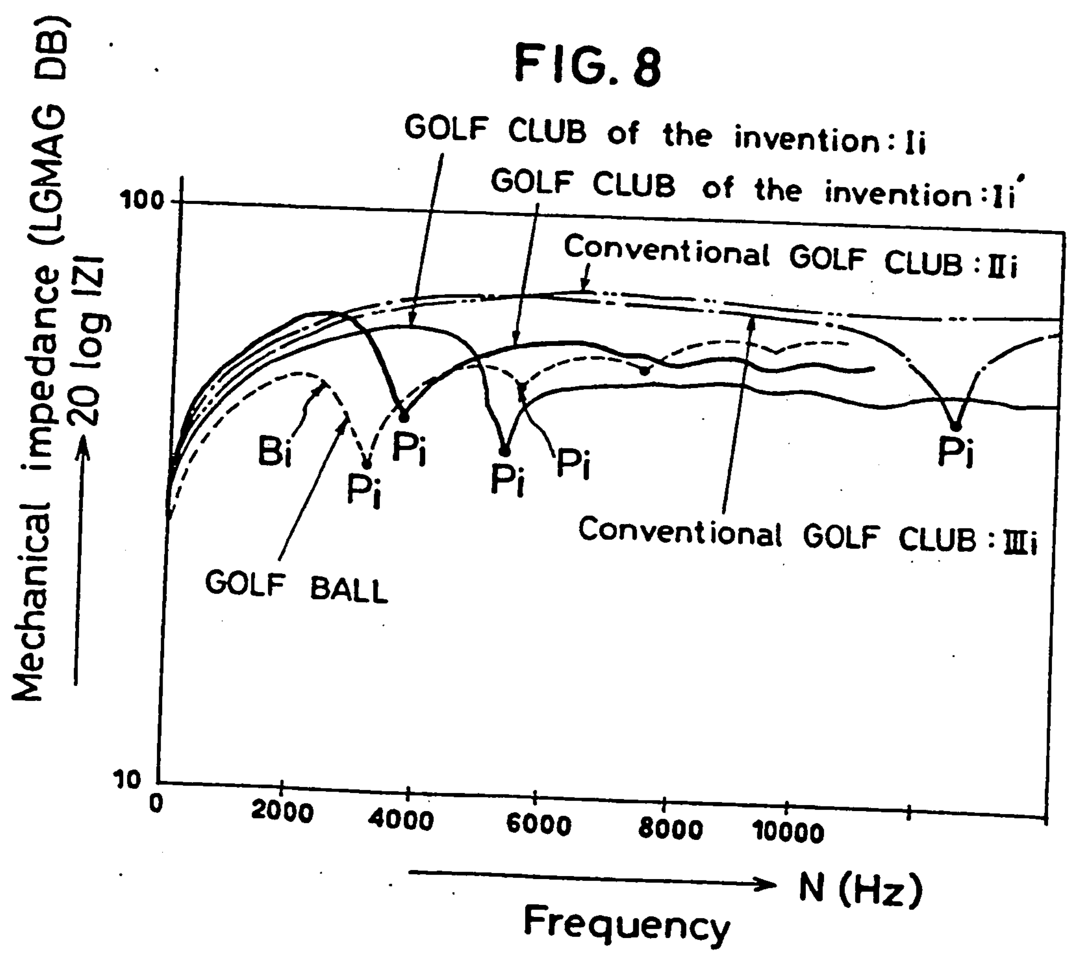

GOLF CLUB of the invention : Ii
GOLF CLUB of the invention : Ii'
Conventional GOLF CLUB : IIi
Conventional GOLF CLUB : IIIi
GOLF BALL
Bi
Pi
Pi
Pi
Pi
Pi
Pi
Mechanical impedance (LGMAG DB)
20 log |Z|
100
10
0
2000
4000
6000
8000
10000
N (Hz)
Frequency

FIG. 9A

FIG. 9B

FIG. 9C

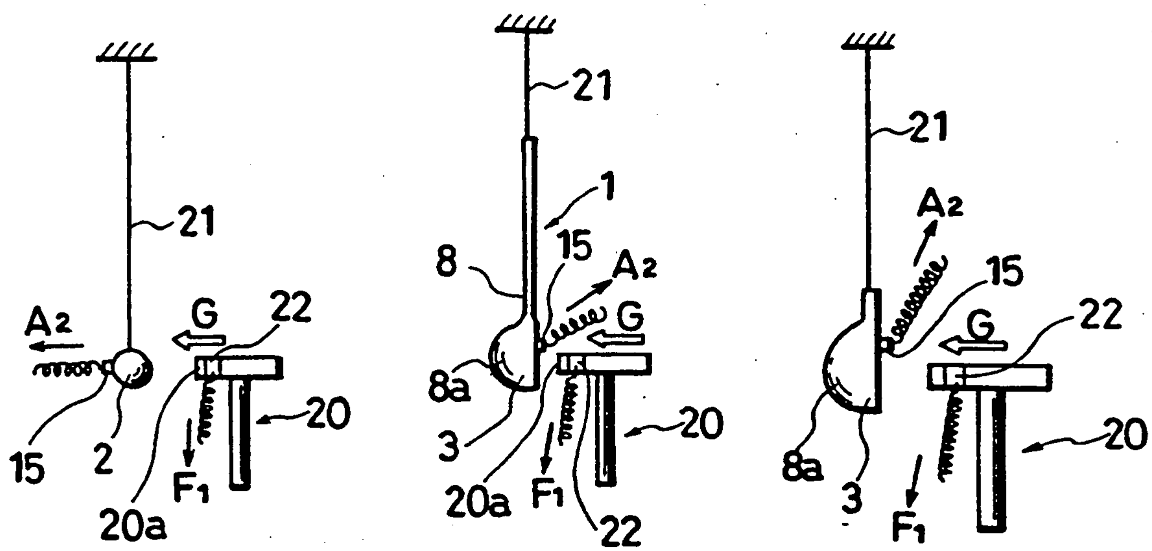
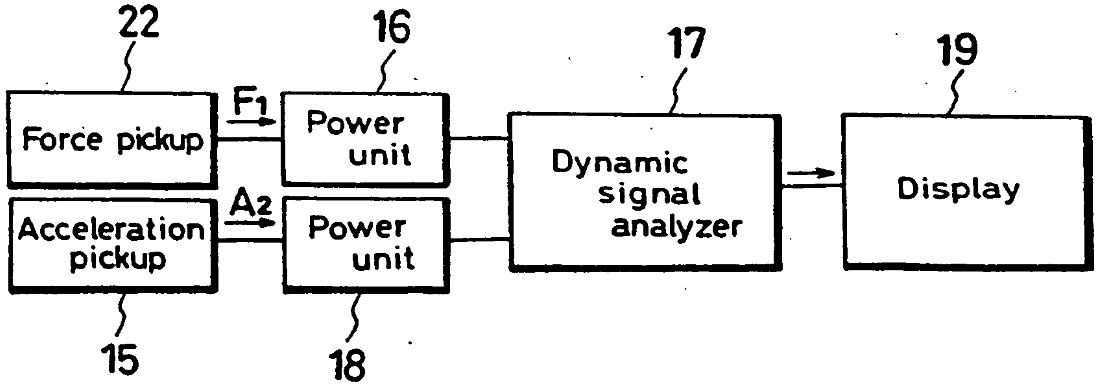


FIG. 10



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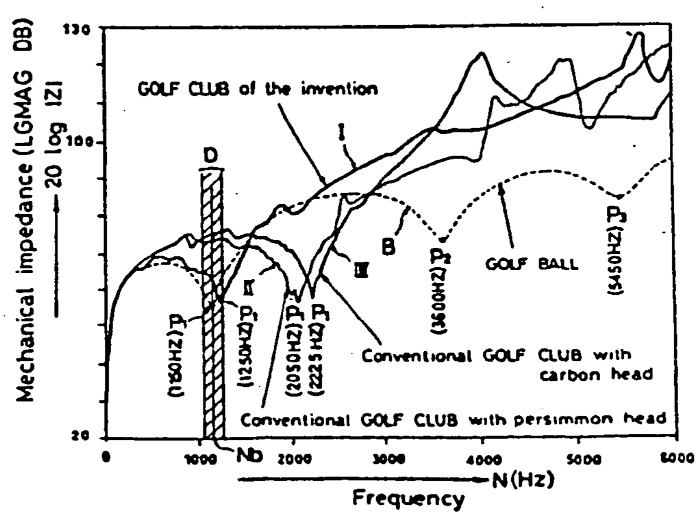
(54) **A ball striking instrument.**

(57) A ball striking instrument of such a structure that at least the main part of the instrument is fabricated so that the mechanical impedance (Z) of the ball striking part takes a minimum value (P1) in a range (D) of mechanical vibration frequency close to the frequency (Nb) at which the mechanical impedance (Z) of the ball to be struck takes a minimum value (P1).

FIG. 1



EP 0 168 041 A3

European Patent Office

EUROPEAN SEARCH REPORT

0168041

Application number

EP 85 10 8558

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl 4)
E	EP-A-0 176 021 (KUEBLER) * claims 1, 2 *	1,3-8, 10	A 63 B 53/00 A 63 B 49/00 A 63 B 59/00
A	US-A-4 291 574 (FROLOW) * page 4, lines 4-35; claims 1, 5, 6 *	1-8,10	
A	US-A-3 945 646 (HAMMOND) * claim 1; figure 1 *	1,3	
A	US-A-4 070 022 (BRALY) * claim 1, figure 4 *	1,2	
A	GB-A-2 056 288 (TSAI CHEN SOONG) * claim 1 *	1,3-8, 10	

TECHNICAL FIELDS SEARCHED (Int Cl 4)

A 63 B 49/00
A 63 B 51/00
A 63 B 53/00
A 63 B 59/00
A 63 B 69/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	21-05-1987	MICHELS N.

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